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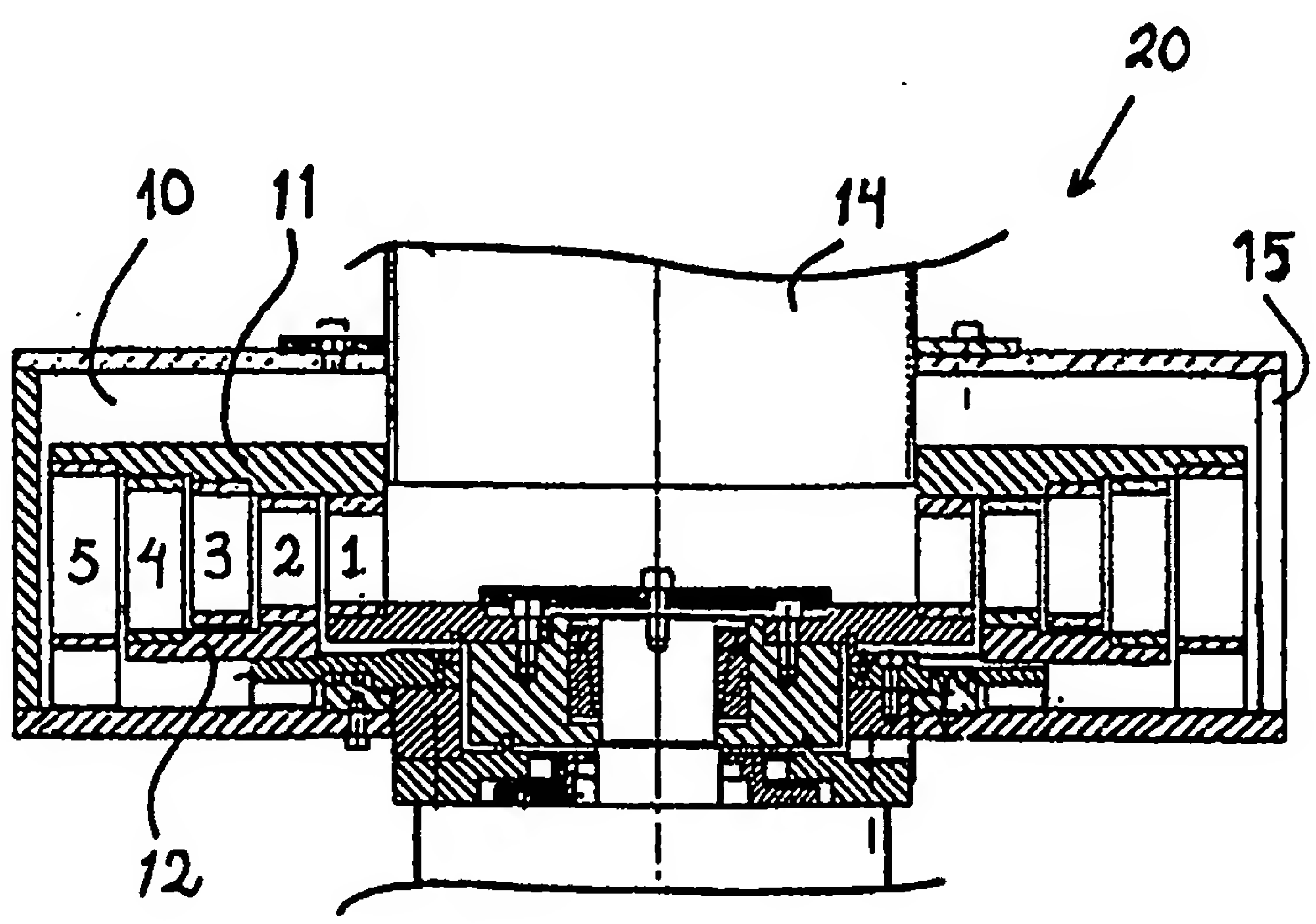

(57) Abstract

The object of the invention is a method for processing pulp stock derived from a pulp or paper mill, which pulp stock contains fibres and/or any other components, such as mineral components, in order to disperse the agglomerations in the pulp stock. The method is characterised in that the pulp stock is supplied to an apparatus operating according to the principle of a double action impact mill (the double action impact mill (20)). The apparatus comprises: a first rotor (11) provided with blades; a second rotor (12), which is coaxial with the first rotor and provided with blades and which is arranged to rotate in a direction being opposite to that of the first rotor; and a feeding opening (14) which opens out to the nave of the rotors. Pulp stock is supplied to the feeding opening (14) which opens to the rotor naves and is caused to flow via the blades of the rotors (11, 12) arranged within each other, to the outermost rotor ring, and to be discharged from there as a discharge flow from the apparatus. The invention also relates to an apparatus for performing the method.

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Method and apparatus for processing pulp stock derived from a pulp or paper mill

The present invention relates to a method and apparatus according to the preambles of the independent claims presented below for processing pulp stock, particularly silted broke in a pulp or paper mill.

TECHNICAL BACKGROUND

Broke is generated in many steps in a paper manufacturing process, and the broke contains fibres and possible fillers, adhesives, coating materials, etc. Thus the broke contains both useful raw material and waste, which must be removed from the recycled raw material. The task of the broke processing system is to return the valuable raw material components of the broke into the process.

Broke pulping

The first processing step is pulping of the broke. There are pulpers at several locations under the paper machine and the coating machine. In break situations the production of the machine can be directed to these pulpers. There are further pulpers adjacent to the glazing calanders and the slitter winders.

The edge trimmings of the slitter winders can be directed to any of the above mentioned pulpers or to a separate edge trimmings pulper. Most often there is a separate pulper for pulping broke rolls.

The system generally also contains a two-stage screening before the pulp deposition and defibration, because the mill broke contains plastics and other impurities.

Pulping means to mix broke in web form with water, so that there is created a pulp stock which can be pumped and where the fibres are at least partly apart from each other.

Broke equalisation is carried out in the pulper. In a dry cellulose or paper sheet the fibres are closely bonded to each other. In order to break the bonds between the fibres the pulp must be soaked in water. Then the fibres also will swell when water penetrates the pores of the fibres. External forces are also required in order to separate the fibres. They are generated by strongly agitating the pulp stock. This is provided by a rotor located in the pulper. It operates like the impeller of a pump; the

pulp flies outwards from the periphery and at the same time a strong suction is created in the centre of the rotor.

The dispersion property of broke paper depends on the paper quality. The dispersion is reduced by paper adhesives, surface treatment and coating. The most easily dispersed paper qualities are newsprint and other uncoated wood-containing paper qualities. Calandering makes it more difficult to disperse the above mentioned paper qualities. Paper qualities which are particularly difficult to disperse are for instance wet strength papers and coated paper qualities as well as kraft liner and kraft paper.

Broke storage

A production line making coated paper qualities has usually separate broke storage towers for uncoated and coated broke. This is because it is desired to portion out the coated broke in a controlled way back to the paper machine, for instance due to ash control of the base paper.

Broke screening and defibration

Screening of the broke stock is the more necessary the higher quality the manufactured final product shall have.

Poorly dispersed broke, or impurities accompanying the broke (for instance plastics, shives, sand), cause problems in the process and breaks at the paper machine.

A modern screening and defibration line for broke typically comprises
- a protective screen, generally a pressure screen provided with a perforated drum,
- broke defibrators,
- a pressurised screen, which is a pressure screen provided with a slit drum or a perforated drum, and
- a broke reject screen, which is either an oscillating strainer or a pressure screen.

The purpose of the protective screen is to remove large solid impurities from the broke, for instance pieces of tape, pieces of threading rope, shives.

The pressurised screen returns to the defibration such fibre clusters which were not dispersed.

The purpose of the broke reject screen is to separate from the pulp such refuse and other solid particles, which must be removed, and to return approved pulp to the screening circulation and back to the process.

If the papers in question contain fillers and corresponding non-organic components, the mineral containing fraction is supplied further to a separate recovery plant (filler recovery).

As noted above, it is very difficult to process the broke from paper qualities, which are provided with adhesives, surface treated and coated. The organic components in the adhesives and the coating slip cause agglomeration of the fibre material and the mineral pigments. The generated agglomerates do not disperse in a satisfying way in known dispersing devices, so most part of the processed material is useless in sense that it can not be returned to the process. Therefore such materials often must be disposed of, for instance by driving them to the dumping area. This is an environmental disadvantage, but primarily it is a substantial loss of fibrous raw material and valuable non-organic filler. A machine producing coated paper can produce such material in an amount of about 10 tons per day. A recovery and reuse of such material in the process would mean great cost savings on a yearly basis.

The object of the invention is to eliminate the above mentioned problems and to provide a method in a pulp or paper mill for processing pulp stock containing fibres and/or any other components in order to disperse agglomerates contained in the pulp stock.

With the method it is also possible to process difficult broke qualities, and thus to recover useful raw materials contained in them, and to return the recovered materials to the process. This processing can also substantially improve the optical properties of the produced paper, in other words increase both the lightness and the opacity.

With the method it is also possible to process pulp stocks containing extractives in an adhering form (agglomerate form) and to disperse the agglomerates contained in these pulp stocks, in order to transform the extractives into a non-adhering form.

These objectives are achieved with the method and the apparatus according to the invention, which are characterised in what is presented below in the characterising parts of the claims.

The term "pulp stock" covers any stock made of a wood-based pulp. The pulp can be mechanical pulp, semi-chemical pulp or chemical so called virgin stock, or it can be any broke flow present in the paper making, or a mixture of said components.

The term "broke processing" covers in this invention also the deinking of printed

paper, where the ink is removed from the fibrous pulp.

Devices operating with the double action impact mill principle are previously known for instance from the Danish patent publication DK 104778, the Finnish patent applications FI 945945, FI 946048 and FI 955474. These devices are characterised in that two coaxial rotors provided with blades are arranged in a housing, whereby the rotors are arranged within each other in the housing and arranged to rotate in opposite directions within the housing.

An apparatus according to the invention comprises
- a first rotor provided with blades,
- a second rotor, which is coaxial with the first rotor and provided with blades, the second rotor being arranged to rotate in the opposite direction regarding the first rotor, so that the rings of the first rotor and the rings of the second rotor are arranged in an intermeshed fashion, and
- a feeding opening which opens to the nave of the rotors.

The material flow to be processed (the pulp stock) is supplied into the feeding opening which opens out to the rotor naves and the material flow is caused to flow via the blades of the rotors arranged within each other, to the outermost rotor ring, and to be discharged from there as a discharge flow from the apparatus.

With this method it is for instance possible to process very different silted broke fractions, both very highly fibrous broke and broke containing a high degree of filler. Thus the silted broke fraction can be coated broke from the pulpers, a flow containing filler and directed to the filler recovery plant, reject from the filler recovery plant, or reject discharged from the screening and defibration plant.

The method is also particularly well applicable for the reduction of extractives adhering to different virgin pulps.

The solid contents of the pulp stock can vary in a wide range, suitably from 3 to 60 %.

According to a suitable embodiment the suspension obtained as the discharge flow from the double action impact mill is recirculated either wholly or partly, one or more times, to the double action impact mill. Another suitable embodiment utilises two double action impact mills connected in series.

An apparatus according to an embodiment is provided with a housing of its own.

The number of rings of the apparatus is at least two. The energy consumption of the apparatus increases when the number of the rings increases, and therefore an optimal number of the rings is probably 2 to 5.

The invention is described in more detail in the enclosed figures, in which

Figure 1A shows in a vertical cross section the double action impact mill used in the method according to the invention;

Figure 1B shows an alternative solution to that of figure 1A;

Figure 2 shows an apparatus of the type in figure 1, in a horizontal cross section;

Figure 3 shows an equipment for processing broke with a method according to the invention;

Figure 4 shows another equipment, where the apparatus according to the invention is used for processing broke;

Figure 5 shows a third equipment, where the apparatus according to the invention is used for processing broke;

Figure 6 shows a fourth equipment, where the apparatus according to the invention is used for processing broke;

Figure 7 shows a fifth equipment, where the apparatus according to the invention is used for processing broke;

Figure 8 shows schematically the broke processing system in a paper mill producing coated paper;

Figures 9a to 9d, 10a to 10d and 11a to 11d show microscope photographs of a sample taken from the reject of a filler recovery plant; and

Figure 12 shows the effect of the method according to the invention on the particle size distribution of the reject from a filler recovery plant.

Figure 1A shows in a vertical cross section the double action impact mill 20 used in the method according to the invention, whereby the mill comprises a housing 10, within which there is disposed a rotor 11 provided with blades 1a, 1b, ..., 3a, 3b, ..., and so on (the individual blades are better seen in figure 2). Within the housing there is also disposed another rotor 12, which is coaxial with the first rotor 11. The

second rotor 12 is also provided with blades 2a, 2b, ..., 4a, 4b, ..., and so on. The blades 1a, 1b, ..., 2a, 2b, ... 3a, 3b, ... of the first rotor 11 and the second rotor 12 are disposed in coaxial rings 1, 2, 3, ... so that the rings 1, 3, 5 of the first rotor 11 and the rings 2, 4 of the second rotor 12 are arranged in an intermeshed fashion. Then the rotors 11 and 12 with their blades can freely rotate in opposite directions. At the end of the housing there is disposed an opening 14 which opens out to the naves of the rotors 11 and 12, whereby this opening acts as the feeding opening of the pulp stock. This feeding arrangement is possible as the axes of the rotors are disposed within each other, as in the solution of the patent application FI 946048. In the wall of the housing there is arranged an opening 15 which opens out to the outermost blade ring, whereby this opening acts as the discharge opening.

The rotors rotating in the opposite directions generate strong centrifugal forces which effectively keep the flow-through in motion, which could not be possible with a stator/rotor-system.

Figure 2, showing an apparatus of the type in figure 1A in a horizontal cross section (however, modified so that each rotor 11, 12 has one ring more than in the apparatus of figure 1), presents the direction of rotation of the rotors. Each rotor can of course also rotate in the opposite direction.

It is not necessary that the peripheral wall of the housing of the double action impact mill is immediately adjacent to the rotor pair, but it can be farther away, whereby the housing can be quite spacious. Then the purpose of the housing is mainly to act as a recovery container for the processed material. Figure 1B shows a solution in which the apparatus used in the method according to the invention is not provided with a fixedly mounted housing of its own. The apparatus comprising the rotor pair 11, 12 is disposed in a container 30 having an opening 14a arranged in connection with the feed opening 14, and having a discharge opening 15a for the processed material flow.

According to the solution of figure 2 the horizontal distance L between the rings 1, 2, 3, ... is about 3 mm and equal between all rings. When required the apparatus can be constructed, or the apparatus can be adjusted, so that the distance L between the adjacent rings increases or decreases towards the outermost ring 7 (not shown in the figure).

According to one embodiment the apparatus can be constructed so that the distance S between the blades of the outermost rings is smaller or larger than the distance

between the blades of the inner rings.

The above mentioned measure can present a possibility to ensure that also coarser material can be supplied to the apparatus (for instance reject pulps containing large agglomerates), but despite that provide a final product which is sufficiently well dispersed. An essential advantage is that the number of blades on the rotor rings and the distances between the rings (tightness) are selected according to the requirements. The distance between the rings, as well as the distance between the blades in the rings, can be arranged so that they decrease towards the outer ring. Then the dispersed agglomerates will pass into ever tighter spaces before the obtained suspension is discharged from the apparatus.

According to figure 2 the blades, which have a rectangular profile in cross section, are turned so that the impact surfaces of the blades are directed radially. For example, in order to increase the impact effect, the blades of one or more rings can also be turned so that the direction of their impact surfaces are different from the radial direction. Of course the blade profile in the cross section can also be replaced by a triangular cross section, whereby the impact surfaces of the blades are not parallel, but they form a certain angle between them.

Figure 3 shows the apparatus used in the invention, where the double action impact mill 20 is connected to a recovery container 16 with a volume of 300 litres in the tests. The recovery container 16 contains a mixer driven by a motor M. The reference numeral 17 is the feed piping and 18 is the discharge piping. The discharge pump is marked by the reference numeral 19.

Figure 4 shows another apparatus, which contains only the double action impact mill 20 and the feed piping 17 and discharge piping 18.

Figure 5 shows a third embodiment of the invention where the material flow accumulated in the recovery container 16 is partly returned to the double action impact mill 20 with the aid of the recirculation piping 21. Of the material supplied to the container 16 this arrangement suitable returns 1/4 ... 1/2 to the double action impact mill 20. The rest is returned to the process via the overflow pipe 18.

Figure 6 shows an apparatus solution which in other respects is similar to that of figure 5, except that two double action impact mills 20 and 20' are connected in series. Instead of returning the material flowing in the overflow pipe 18 to the process it is directed to the second double action impact mill 20', from which the material is

discharged via the pipe 18'.

Figure 7 shows an apparatus solution which in other respects is similar to that of figure 6, except that there is no material recirculation to the first double action impact mill 20.

Tests

A factory test was made where samples were taken from the broke stock processing line of a paper mill producing coated paper, and these samples were supplied to a double action impact mill for processing. The test was made under operating conditions, so that small side flows were supplied to the double action impact mill from the sampling points.

Sampling points:

The figure 8 shows the marked sampling points 1 to 4 in a very schematically presented broke process in a paper mill.

No. 1 at the flow input to the filler recovery plant from the broke processing and screening section before the dispergator (the point is before the Supraton dispergator, or before the double action impact mill, respectively);

No. 2 after the broke recovery container (broke tower);

No. 3 fibrous reject after the broke screening and defibration;

No. 4 reject from the filler recovery plant.

Samples were taken at each test point both before the double action impact mill and after it. At the sampling point no. 1 a sample was taken also after the Supraton dispergator. This sample acted as a reference for the double action impact mill, because the Supraton dispergator and the double action impact mill were connected in parallel.

The test run variables were:

1) the feed volume to the double action impact mill,
2) the rotational speeds of the rings in the double action impact mill,
3) the effect of the recirculation in the double action impact mill on the decomposition result,

4) series connection of a number of double action impact mills.

The following laboratory analyses were carried out from the samples:

All samples were photographed through a microscope. The ash and consistency regarding the flows coming to the double action impact mill (input samples) were determined.

For some samples were further determined the SR numbers (drainage resistance, Schopper-Riegler) and the particle size distribution (Sedigraf). Further, test sheets with a laboratory sheet mould, using as partial components the samples obtained at different test points were produced.

Results

The solid contents (consistency):

test point 1:	40 %
test point 2:	4,3 %
test point 3:	7,2 %
test point 4:	17 %

Figures 9a to 9d show microscope photographs (enlargement 90x) of a sample taken at the test point 4, which was unprocessed (9a), once processed in the double action impact mill (9b), twice processed in the double action impact mill (9c), and processed three times in the double action impact mill (9d). In the figures it can be seen that the unprocessed sample (9a) contained large filler agglomerates, and that every cycle through the double action impact mill caused a substantial reduction of the particle size.

Figures 10a to 10d show another similar test result, however, taken at another factory, where the sample corresponded to the above mentioned test point 4. The enlargement is 90x. Figure 10a represents an unprocessed sample, figure 10b represents a sample which is processed once in the double action impact mill, figure 10c represents a sample which is processed twice in the double action impact mill, and figure 10d represents a sample which is processed three times in the double action impact mill. Also these figures show the effect of the double action impact mill in dispersing the pigment agglomerates.

A test was also made, where the effect of the double action impact mill on the sample from the test point 4 was observed. The double action impact mill was con-

nected before the tank before the cyclone cleaner equipment of the filler recovery plant. The figures 11a to 11d show microscope photographs (90x) of the samples taken at the test point 4: before (11a) the double action impact mill was connected to the process, 1.5 hours later (11b), 3 hours later (11c), and 4.5 hours later (11d).

Figure 12 shows the effect of the method on the particle size distribution of the reject from a filler recovery plant. The x axis of the figure represents the particle size and the Y axis represents the undercut, i.e. the proportion of material having a particle size which is below the particle size marked on the X axis. The light columns represent material which is not processed in the double action impact mill. The dark columns represent material which is processed once in the double action impact mill. Material with a particle size smaller than 15 μm is in practice accept, useful for the process. The accept ratio of untreated material is only about 27 %, while the accept ratio of material processed once increased to about 91 %.

In the above described tests was used a double action impact mill with three pin rings in the upper rotor and two pin rings in the lower rotor. The rotational speed of the motor for the upper rotor was 1500 rpm, and the rotational speed of the motor for the lower rotor was 2000 rpm. The maximum flow fed into the double action impact mill was 6 m^3/hour.

It is of course possible to obtain better results than those presented above by optimising the running conditions.

According to a particularly recommendable manner to run the apparatus the rotational speed of its outermost ring is 40 to 80 m/second.

A factory test was also performed, where the pulp after the broke tower was processed only in the manner according to the invention, in a double action impact mill, after which the pulp was run in the paper machine. The paper's technical properties were at least as good as in normal operating conditions. The retention was improved and the filler consumption decreased, because the pigment originating from the coating replaced fresh filler.

On the basis of the tests we can see that the invention provides essential advantages. When the apparatus according to the invention is connected to a broke processing equipment it would make it possible to substantially reduce the size of the cyclone cleaning equipment, which at present comprises 6 stages. The broke processed with an apparatus according to the invention, i.e. the feed to the cyclone cleaning plant,

would require only a 2-stage cyclone cleaning.

Also laboratory sheets were made with the aim to simulate the quality of the paper made in the paper machine in a case where the pulp after the broke tower is processed only by a double action impact mill, after which the pulp is supplied to the paper machine.

Thus about 15 % pulp after the broke tower was used for the laboratory sheets. The rest was material supplied normally to the paper machine (virgin pulp, pigments, etc). For comparison we made three series, in which the pulp after the broke tower was a) unprocessed, b) once processed with the double action impact mill ("1 run"), and c) twice processed with the double action impact mill ("2 runs"). For each series the consistency, ash, charge and turbidity of the broke pulp were measured. The results are presented in table 1. For each series were made sheets containing 15 % broke pulp, and then we measured the lightness and opacity. The results are presented in table 2.

Table 1: Properties of the broke pulp

	Unprocessed	1 run	2 runs
Consistency, %	11.74	8.44	18.54
Ash, %	84.1	84.3	84.8
Charge	-57.3	-46.3	-53.6
Turbidity	114	18	26

Table 2: Optical properties of the laboratory sheets as a function of the processing of the broke pulp component

	Unprocessed	1 run	2 runs
Lightness, % (ISO)			
- sheet's upper side	84.42	85.85	86.30
- sheet's lower side	83.84	85.65	86.16
Opacity, %	71.72	76.31	75.53

From the results presented in table 2 it can be found that the processing of the broke pulp component in the double action impact mill will have a surprisingly advantageous effect on the optical properties of the paper. An increase in the lightness by 1 to 1.5 percent units is usually regarded as a significant achievement. Traditionally an increased lightness is obtained by adding bleached cellulose, which again lowers

the opacity, or by adding an expensive titanium oxide pigment or corresponding pigment.

On the basis of the results presented in table 1 it is also proofed that the lightness and opacity of the paper can be increased simultaneously by processing the broke pulp one or more times in a double action impact mill, and by supplying the so processed pulp flow to the paper making.

From the results presented in table 1 it can also be observed that the turbidity of the water phase of the pulp stock decreases quite significantly as a result of the processing in a double action impact mill. The high turbidity of the water phase of an unprocessed pulp stock is due to materials in colloidal form which later adhere particularly to the drainage equipment of the paper machine. Such materials are typically extractives, such as resin and latex. The extractive in colloidal form, i.e. the adhering resin or the like extractive, is an agglomerate made up of small particles, and any latex particles will accumulate on the surface of this agglomerate. Tests made have shown that the processing in a double action impact mill removes these adhering agglomerates, either by bonding them to fibres or pigment particles, or by dispersing them into small particles which will not adhere. Also the fact that the charge of the pulp stock remains almost constant speaks in favour of an effect mechanism of this kind.

On the basis of the above mentioned results it is obvious that the amount of adhering extractives of any pulp stock containing extractives can be reduced by processing the pulp stock with the method according to the invention. The pulp stock can be coated broke, as in the test described above, another reject flow, or a fresh pulp (mechanical, semi-chemical, or chemical), which is processed in connection with the pulp making (for instance before the drying of the cellulose) or in connection with the paper making, before said pulp is supplied to the paper machine. It is also possible to supply talc or some other dispersing agent together with said pulp stock into the double action impact mill, so that the dispersing agent will "capture" the dispersed particles and prevents the creation of inconvenient agglomerates. Particularly mechanical pulps, such as thermomechanical pulp, have high contents of extractives. It would be very difficult to feed talc or dispersing agent into a pressurised process equipment, but the problem could be solved when the pulp is processed in a separate process step according to the invention.

The above mentioned embodiments of the invention are only examples of how the inventive idea can be realised. To a person skilled in the art it is obvious that differ-

ent embodiments of the invention may vary within the scope of the claims presented below.

Claims

1. Method for processing pulp stock derived from a pulp or paper mill, which pulp stock contains fibres and/or any other components, such as mineral components, in order to disperse the agglomerations in the pulp stock, **characterised** in that the pulp stock is supplied to an apparatus operating according to the principle of a double action impact mill (the double action impact mill (20)), the apparatus comprising
- a first rotor (11) provided with blades (1a, 1b, ..., 3a, 3b, ...);
- a second rotor (12), which is coaxial with the first rotor and provided with blades (2a, 2b, ..., 4a, 4b, ...), and which is arranged to rotate in a direction being opposite to that of the first rotor, so that the rings (1, 3, 5, ...) of the first rotor (11) and the rings (2, 4, ...) of the second rotor are arranged in an intermeshed fashion; and
- a feeding opening (14) which opens out to the nave of the rotors (11, 12), whereby pulp stock is supplied to the feeding opening (14) which opens out to the rotor naves and is caused to flow via the blades of the rotors (11, 12) arranged within each other, to the outermost rotor ring, and to be discharged from there as a discharge flow from the apparatus.

2. The method according to claim 1, **characterised** in that the pulp stock is silted broke containing fillers and/or coating pigments.

3. The method according to claim 1 or 2, **characterised** in that the solid contents of the pulp stock varies from 3 to 60 %.

4. The method according to claim 2 or 3, **characterised** in that the silted broke is coated broke coming from pulping.

5. The method according to claim 2 or 3, **characterised** in that the silted broke is a flow containing fillers directed to a filler recovery plant.

6. The method according to claim 2 or 3, **characterised** in that the silted broke is reject from the filler recovery plant.

7. The method according to claim 2 or 3, **characterised** in that the silted broke is reject discharged from the broke screening and defibration plant.

8. Method for increasing the optical properties of paper, i.e. the lightness and opacity, **characterised** in that coated broke coming from pulping is processed in a double action impact mill with a method according to any of the claims 1 to 3, after

which it is directed as one component to the paper machine.

9. Method for lowering the contents of adhesive extractive in a semi-chemical or chemical pulp, **characterised** in that the stock made of said pulp is processed in a double action impact mill with a method according to claim 1, after which the processed stock is directed to the paper machine or dried.

10. The method according to claim 9, **characterised** in that also talc or other dispersing agent is supplied to the double action impact mill.

11. The method according to any previous claim 1 to 10, **characterised** in that the suspension obtained as a discharge flow from the double action impact mill is recirculated either wholly or partly, one or more times, to the double action impact mill.

12. Apparatus (20) intended for processing a pulp stock derived from a pulp or paper mill, which pulp stock contains fibres and/or any other components, such as mineral components, in order to disperse the agglomerations in the pulp stock, **characterised** in that the apparatus comprises:
- a first rotor (11) provided with blades (1a, 1b, ..., 3a, 3b, ...);
- a second rotor (12), which is coaxial with the first rotor and provided with blades (2a, 2b, ..., 4a, 4b, ...), and which is arranged to rotate in a direction being opposite to that of the first rotor, so that the rings (1, 3, 5, ...) of the first rotor (11) and the rings (2, 4, ...) of the second rotor are arranged in an intermeshed fashion; and
- a feeding opening (14) which opens to the naves of the rotors (11, 12).

13. The apparatus according to claim 12, **characterised** in that one of the rotors (11, 12) or both rotors (11, 12) comprise at least two rings, and that the rings (1, 3, 5, ...) of the first rotor (11) and the rings (2, 4, ...) of the second rotor are arranged in an intermeshing fashion.

14. The apparatus according to claim 12 or 13, **characterised** in that the rotors (11, 12) are disposed in a housing, and that the feeding opening (14) opens out to the end of the housing (10), and that a discharge opening (15) for the discharge flow is arranged in the wall of the housing, so that the discharge opening opens out towards the ring of the outermost rotor.

15. The apparatus according to claim 12, 13 or 14, **characterised** in that the distance (S) between the blades of the outermost rings is smaller than the distance between the blades of the inner rings.

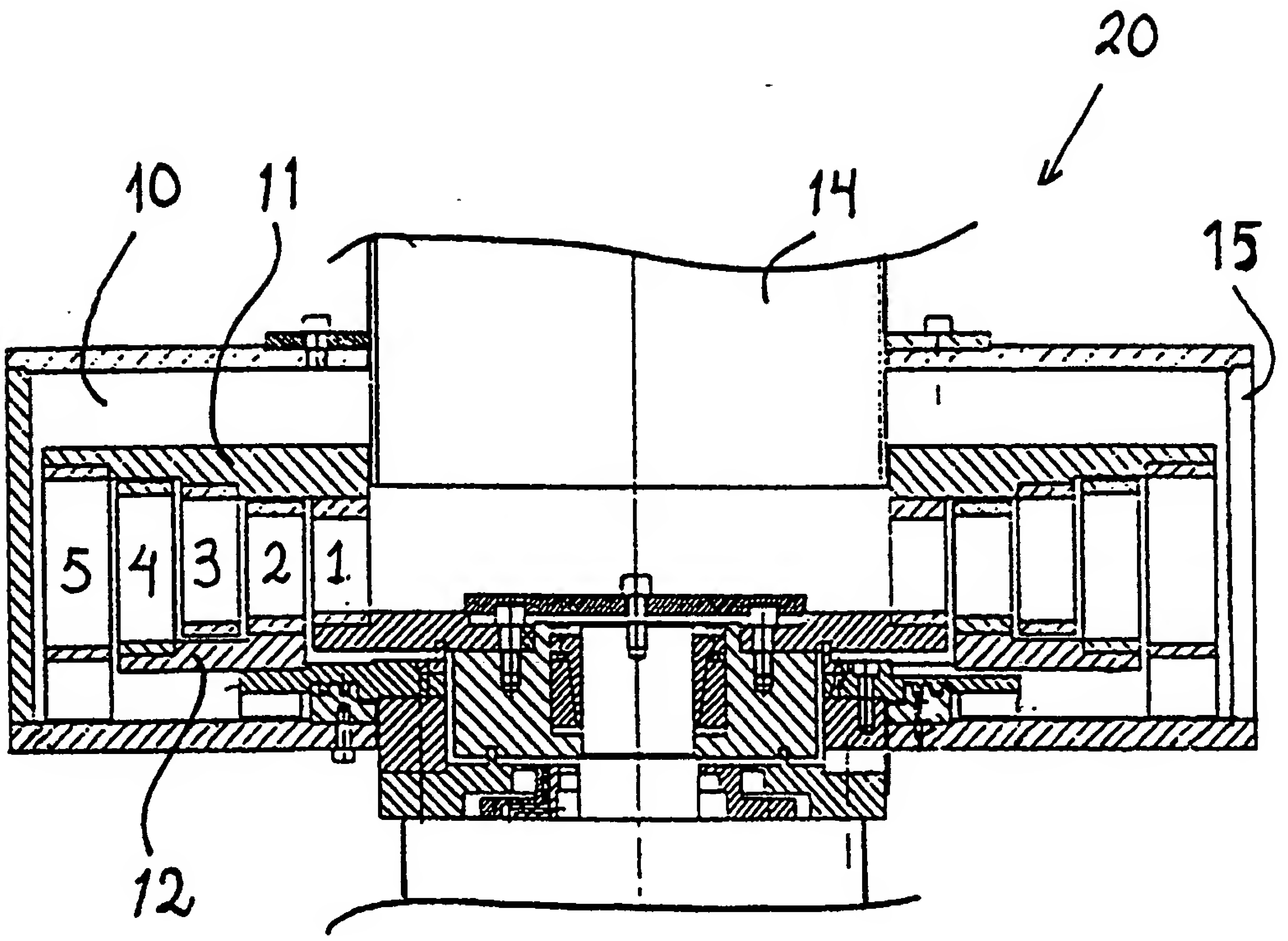


FIG. 1A

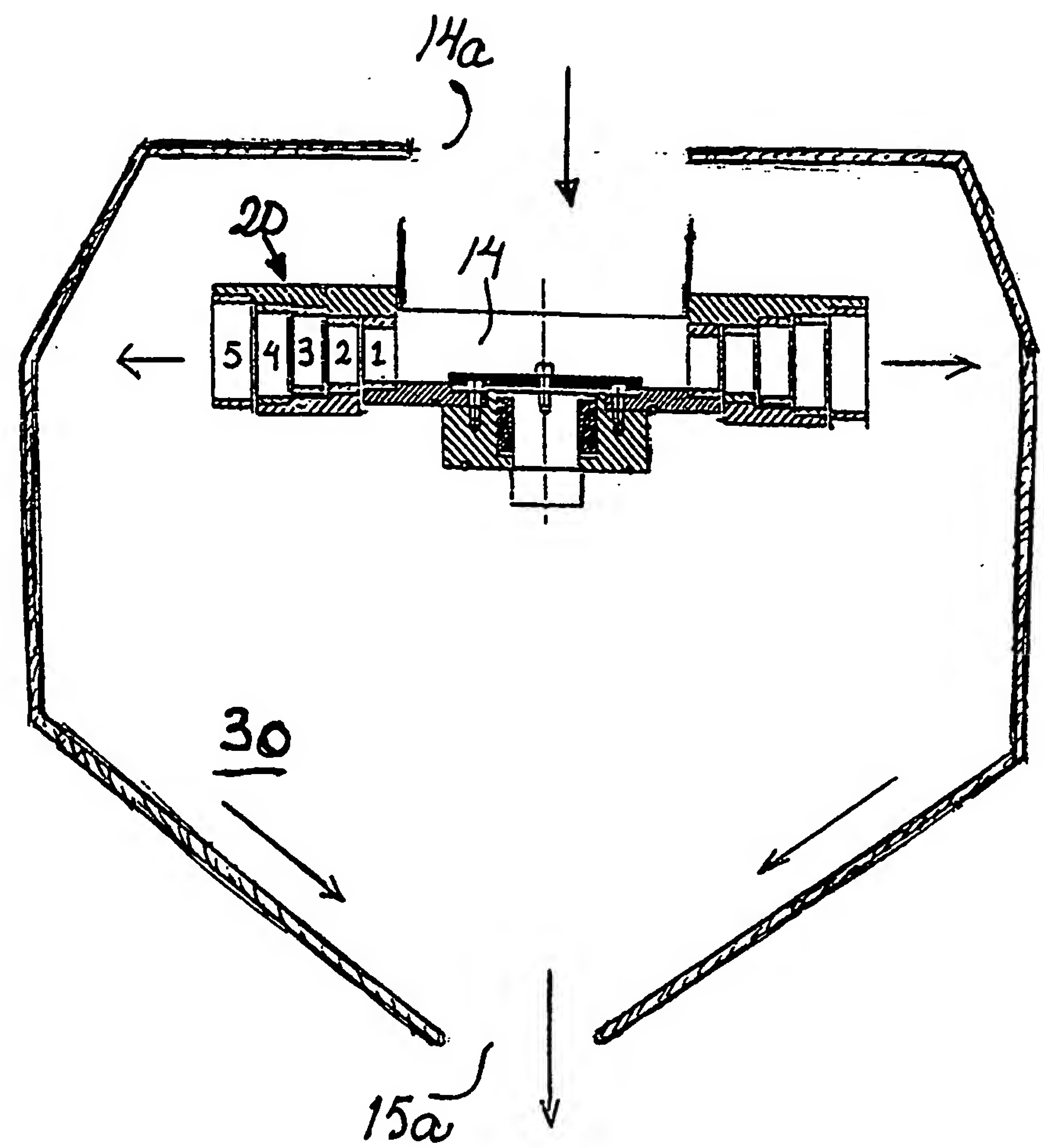


FIG. 1B

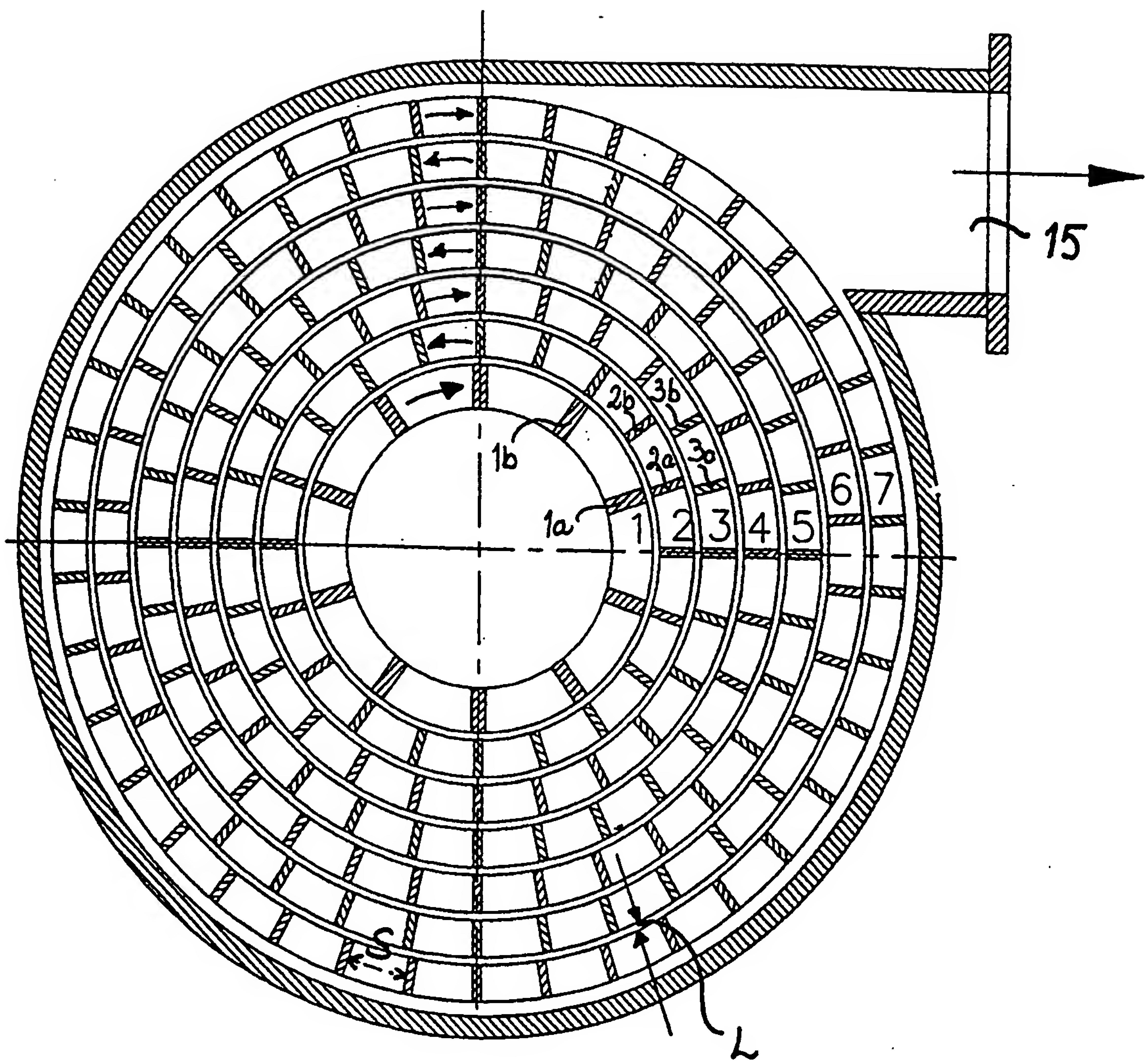


FIG. 2

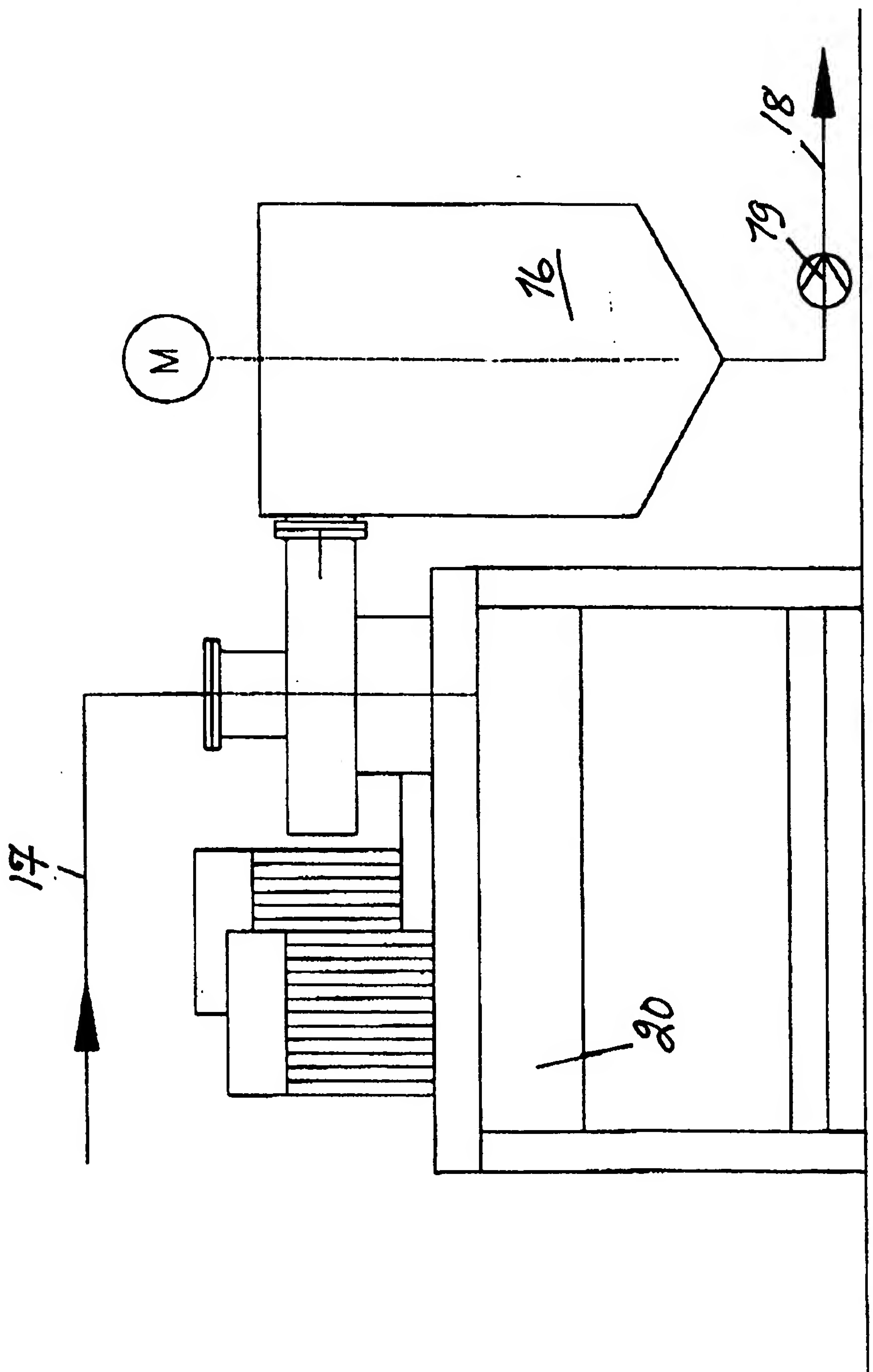


FIG.3

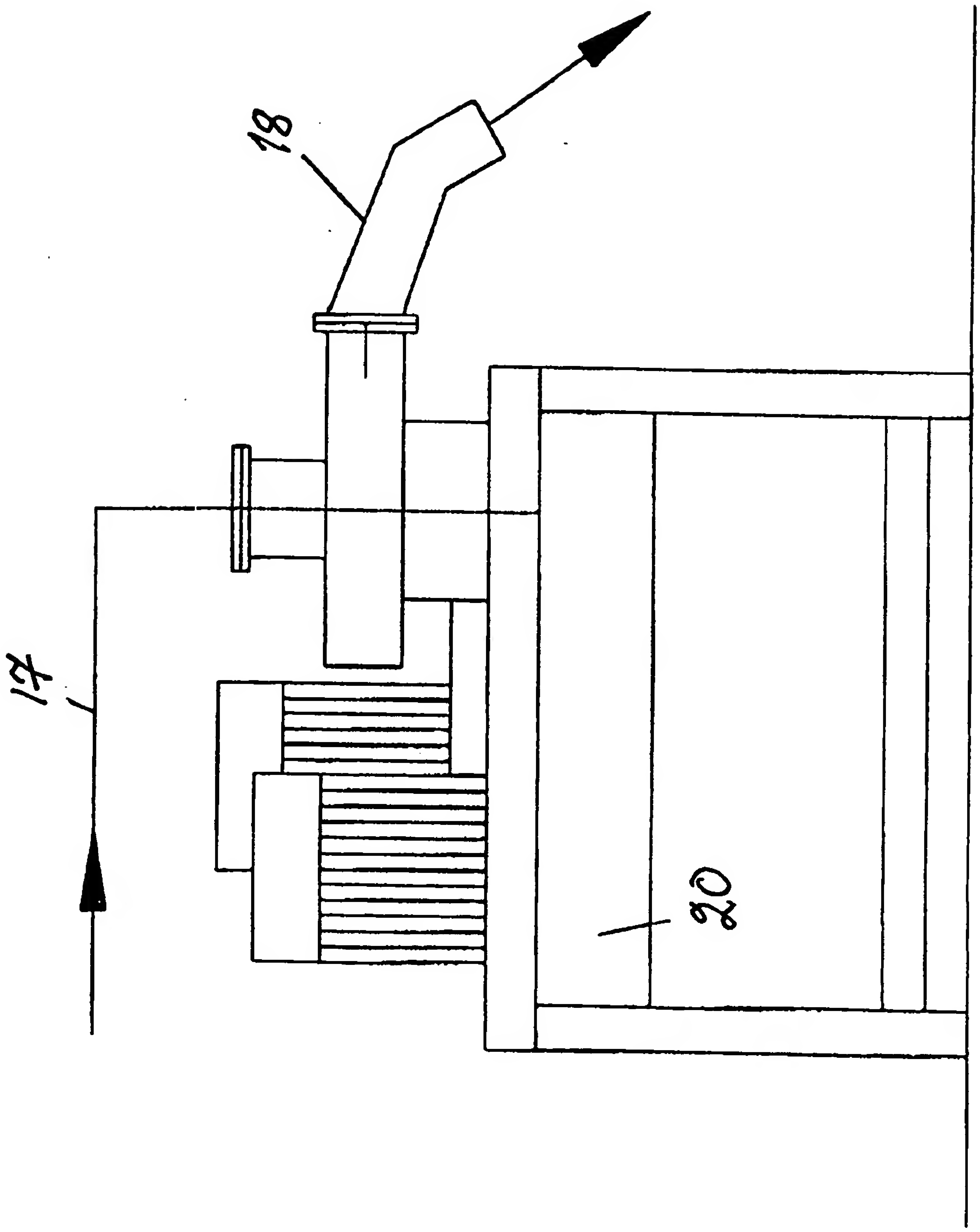


FIG.4

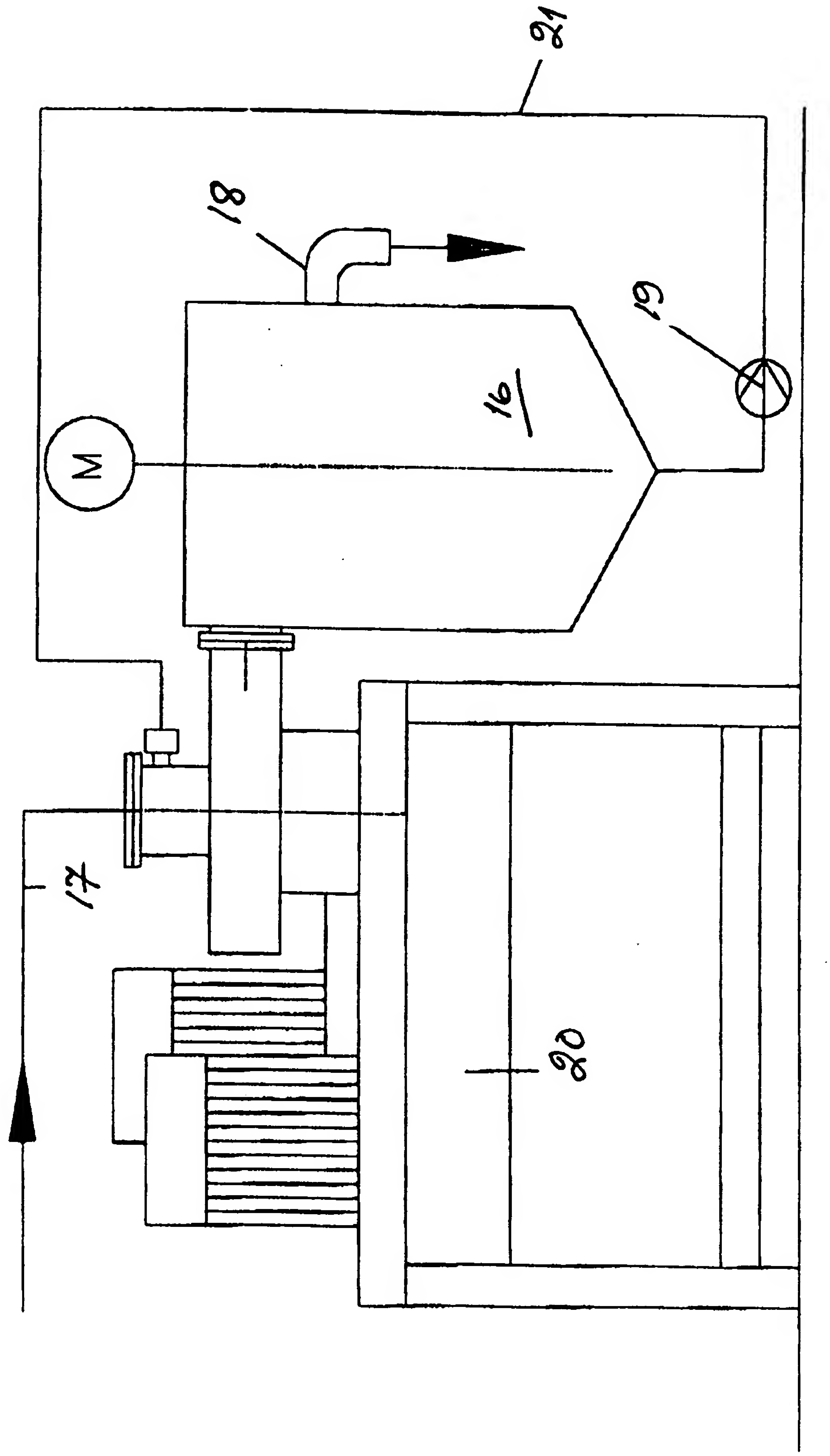


FIG.5

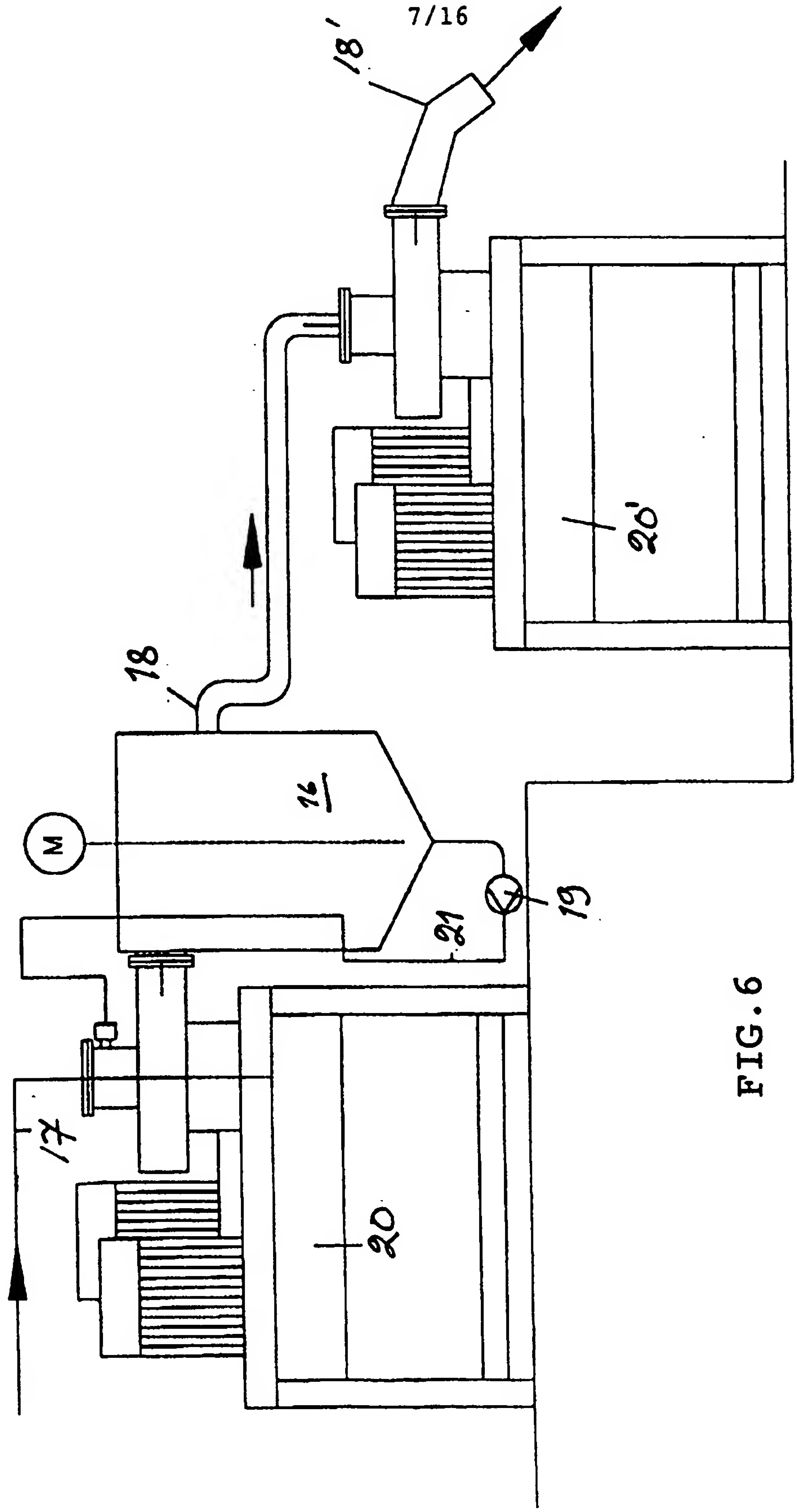


FIG.6

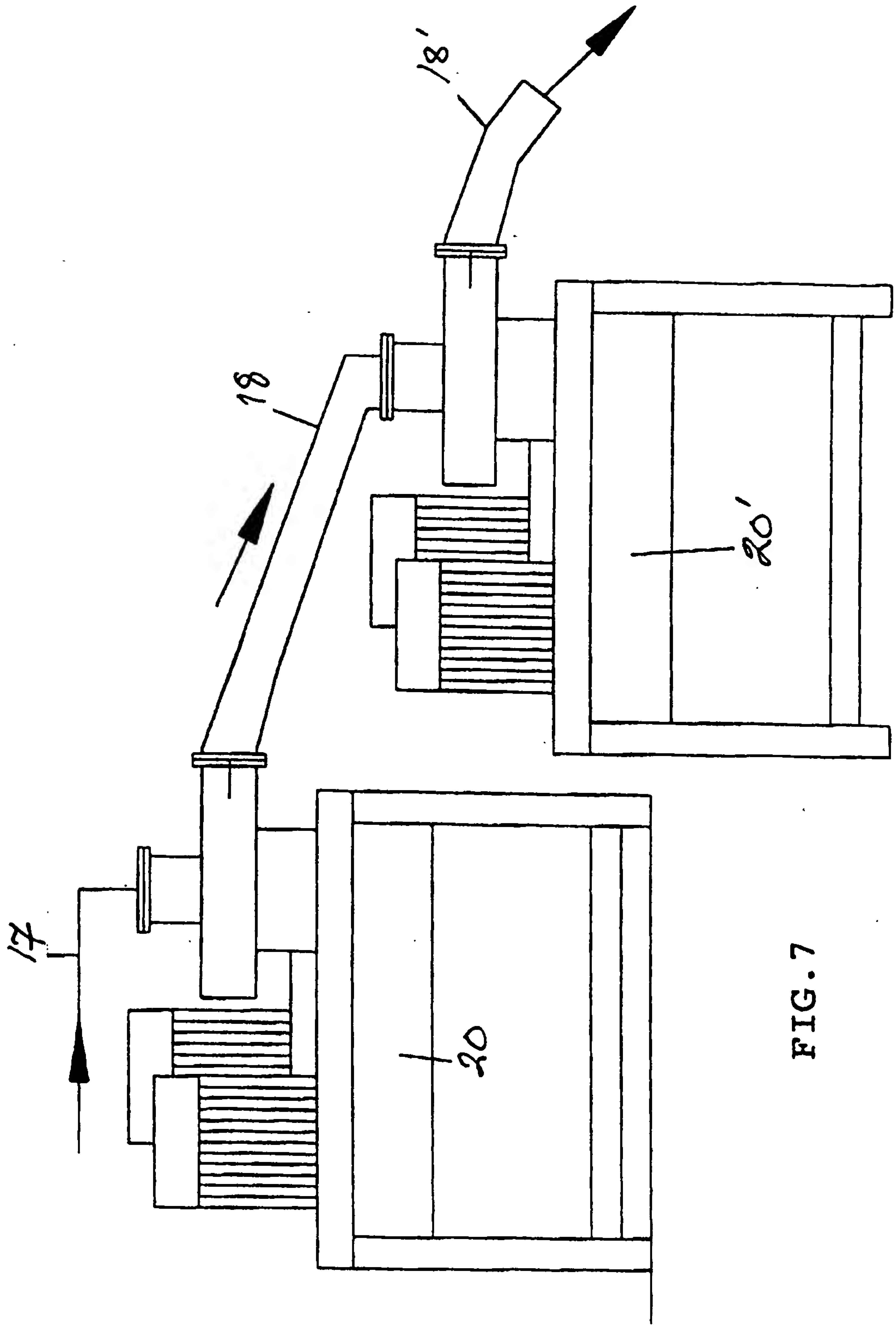


FIG.7

Processing of broke

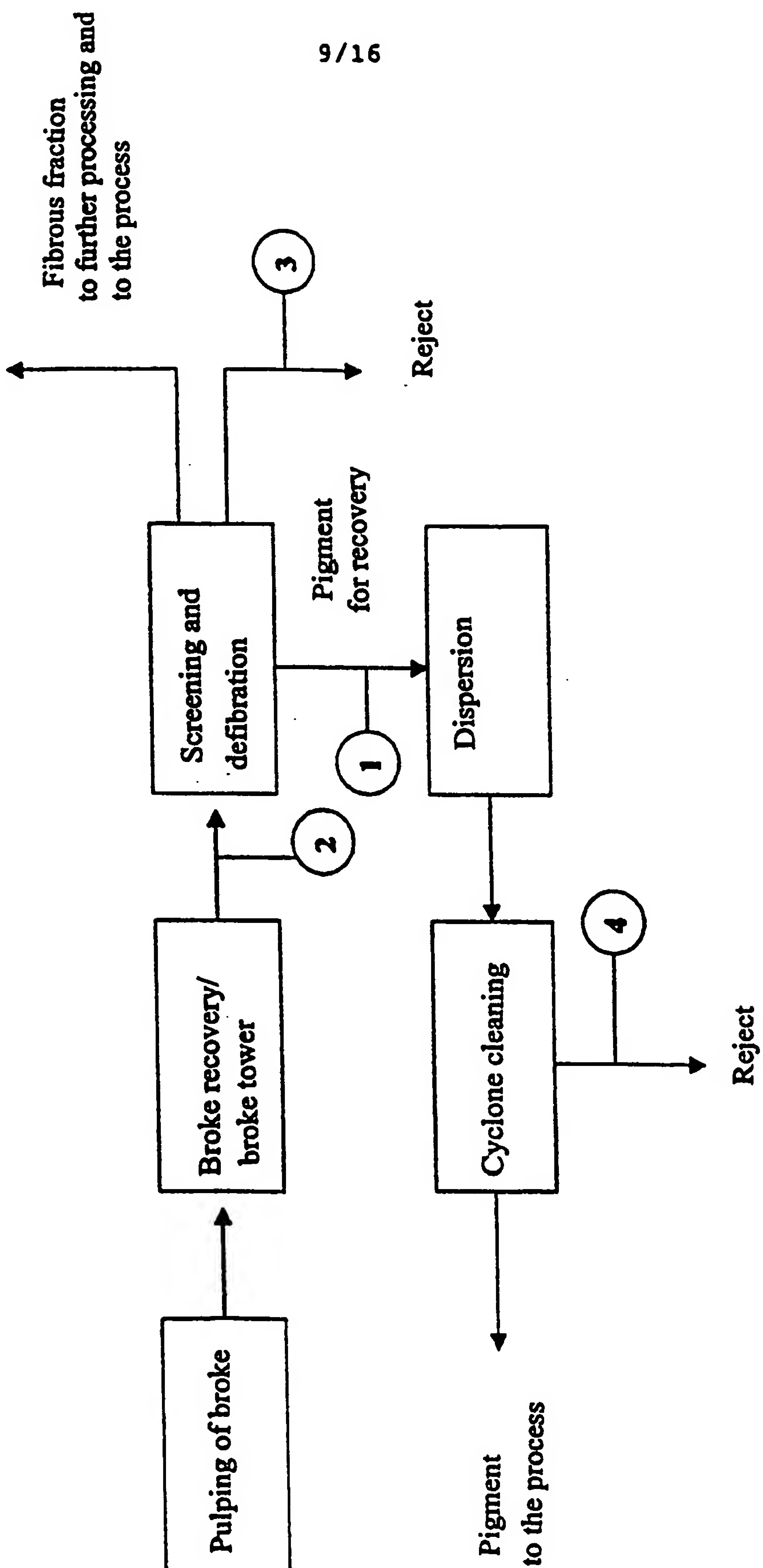


FIG. 8

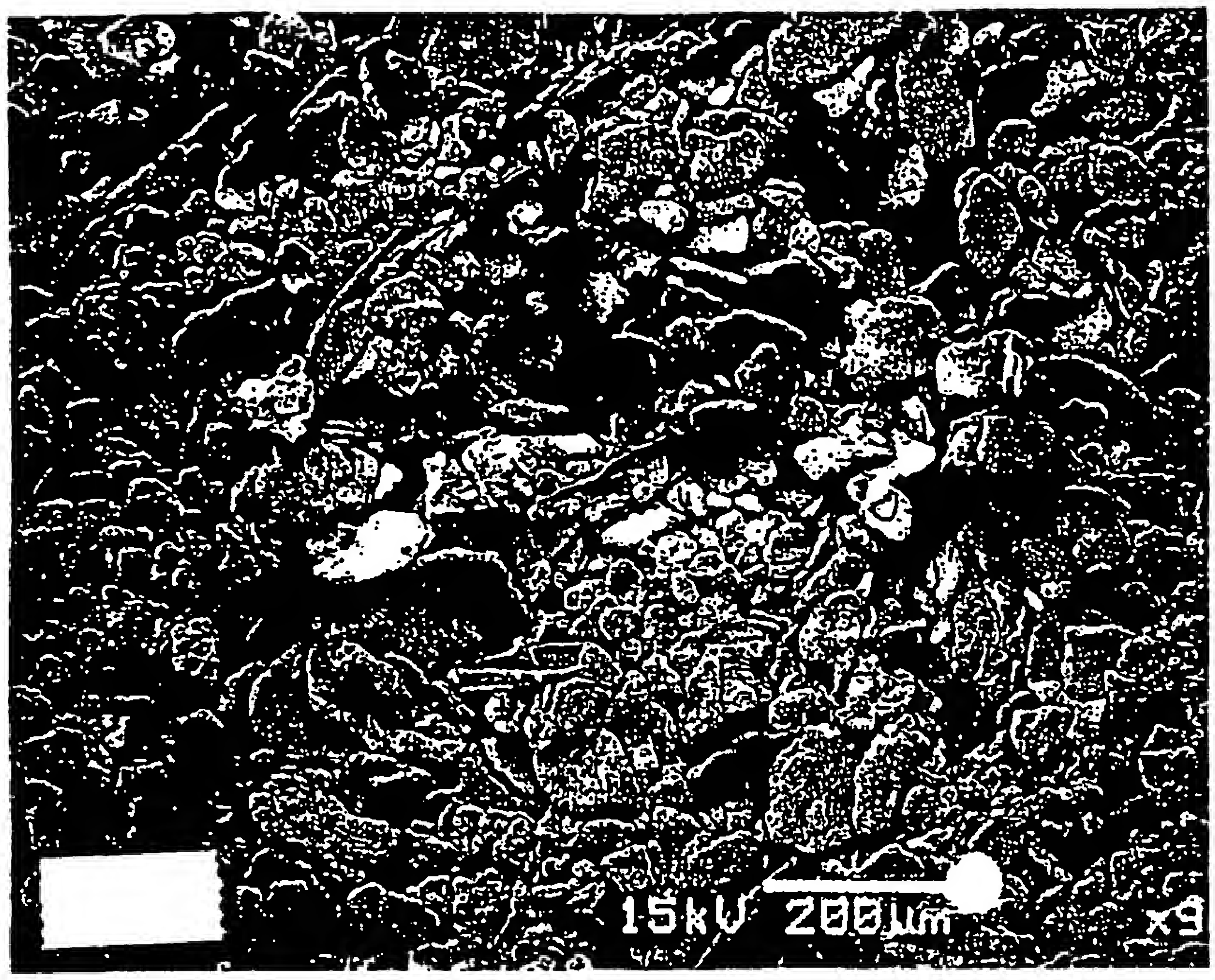


FIG.9a

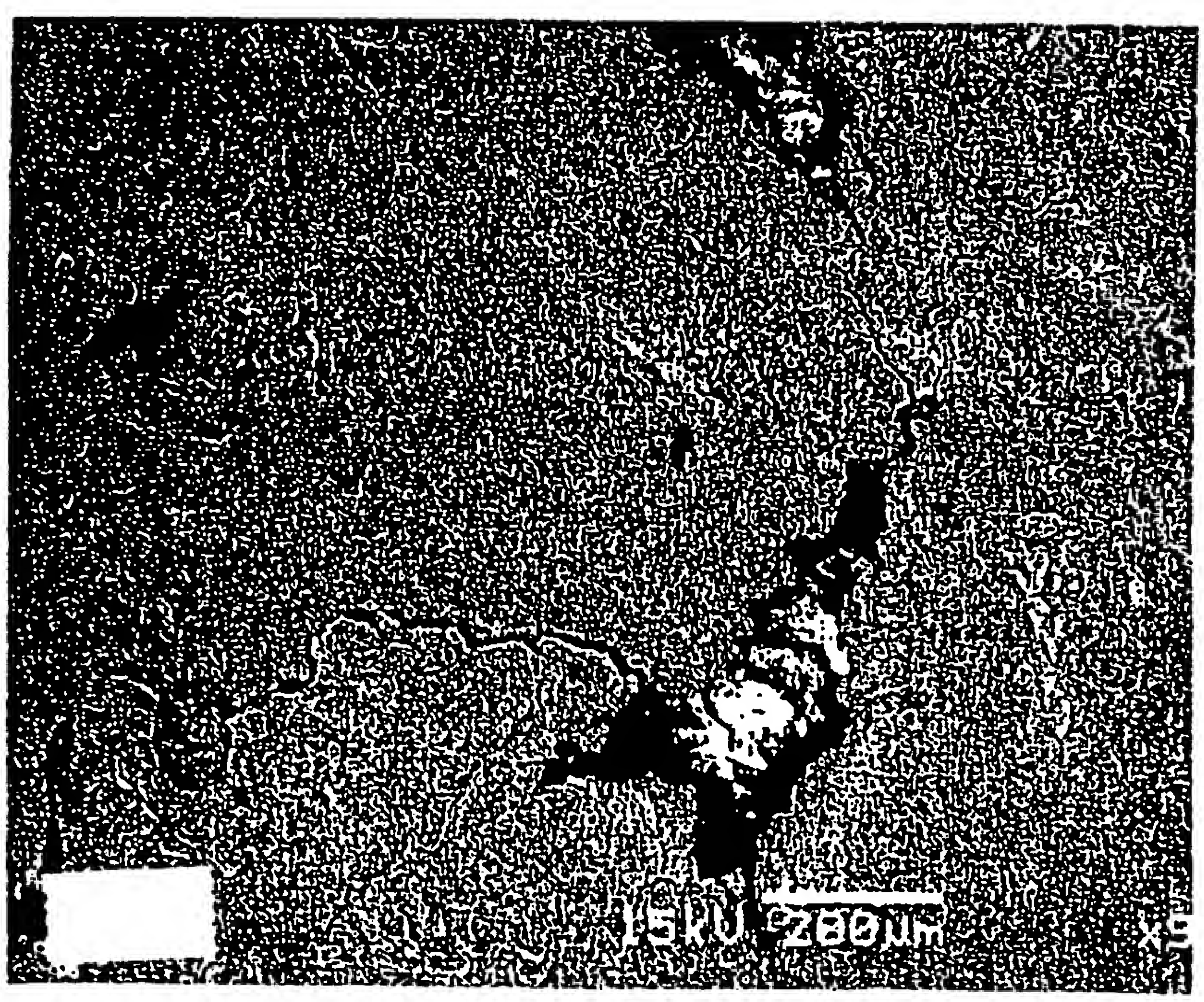


FIG.9b

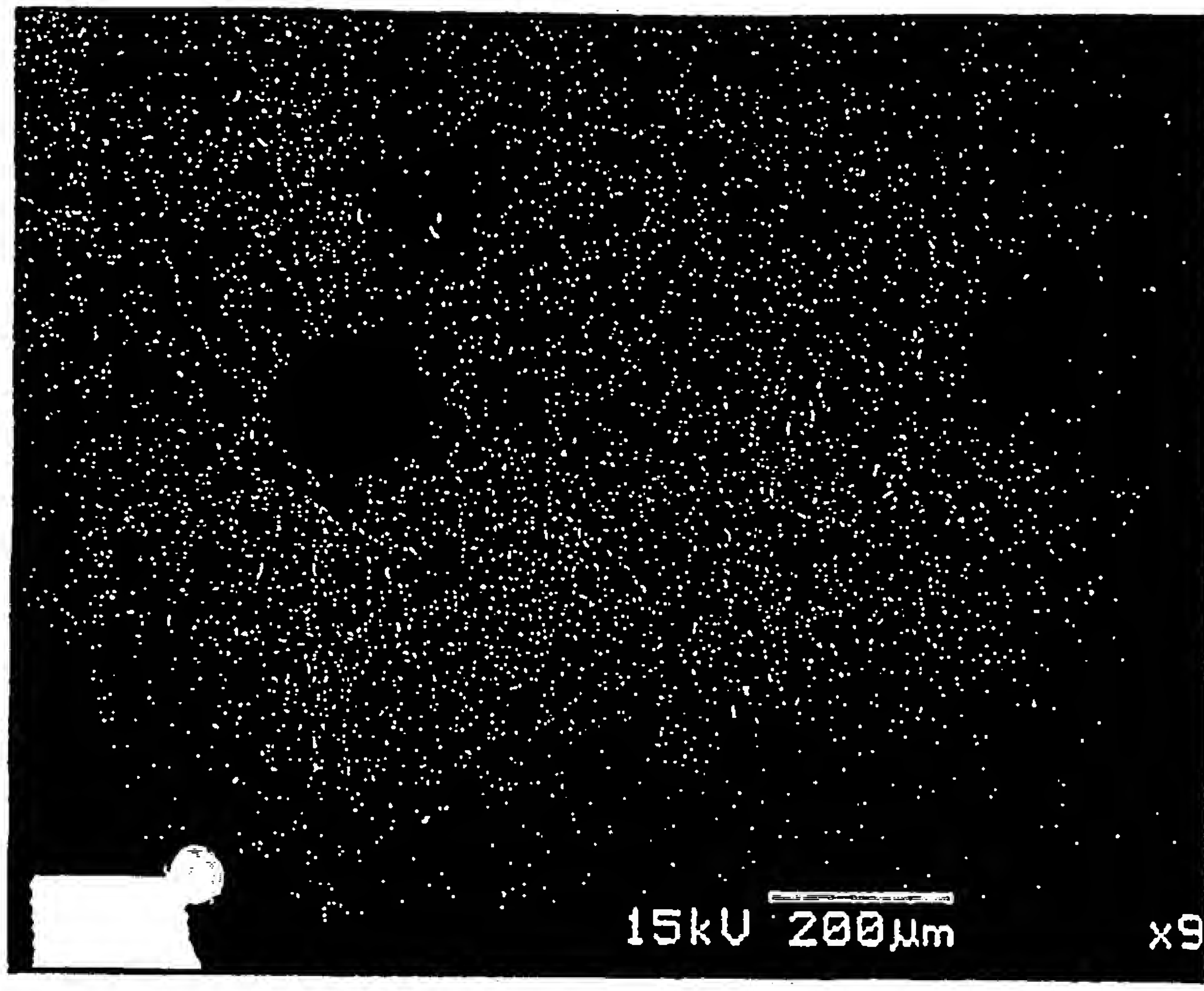


FIG.9c

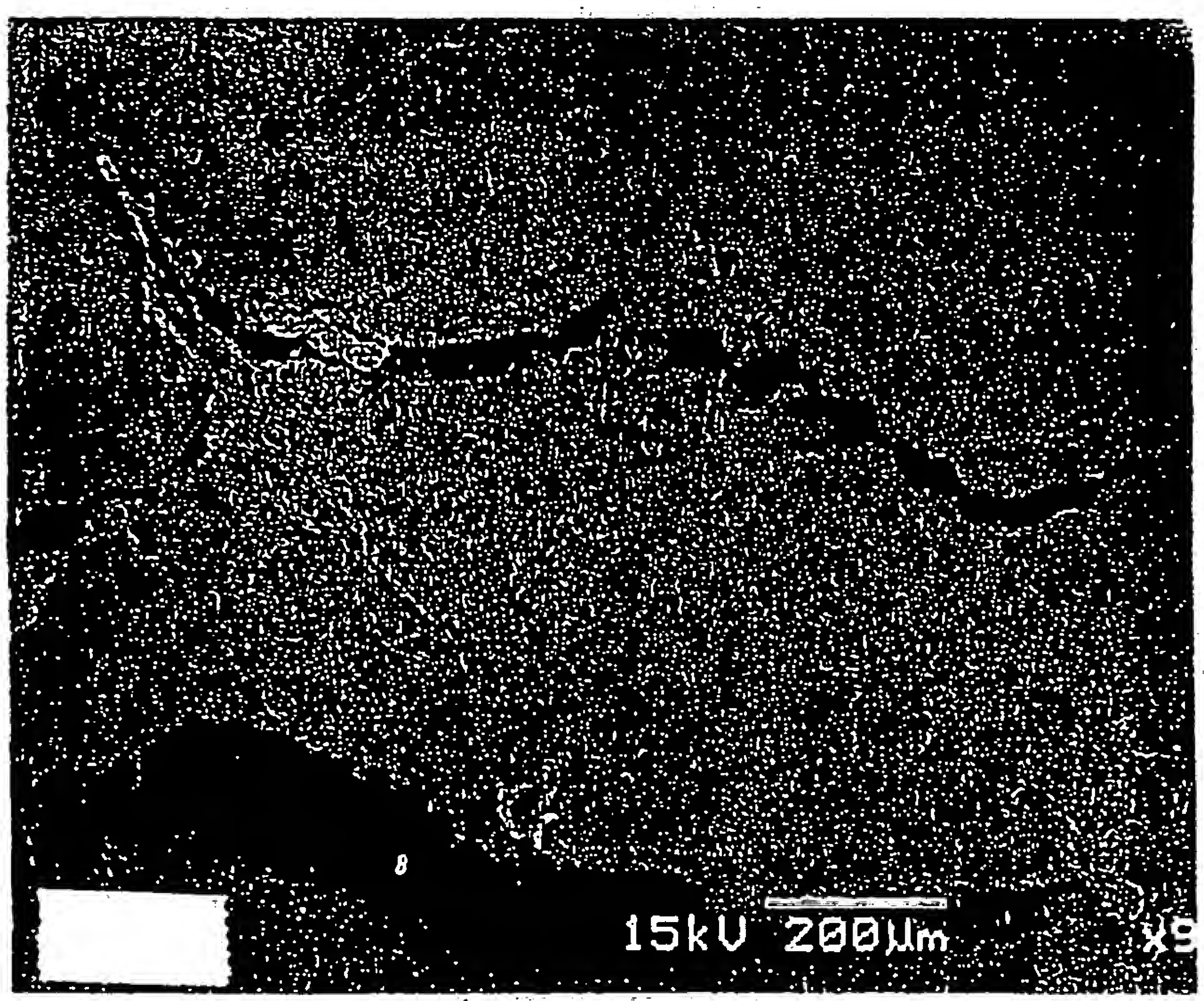


FIG.9d

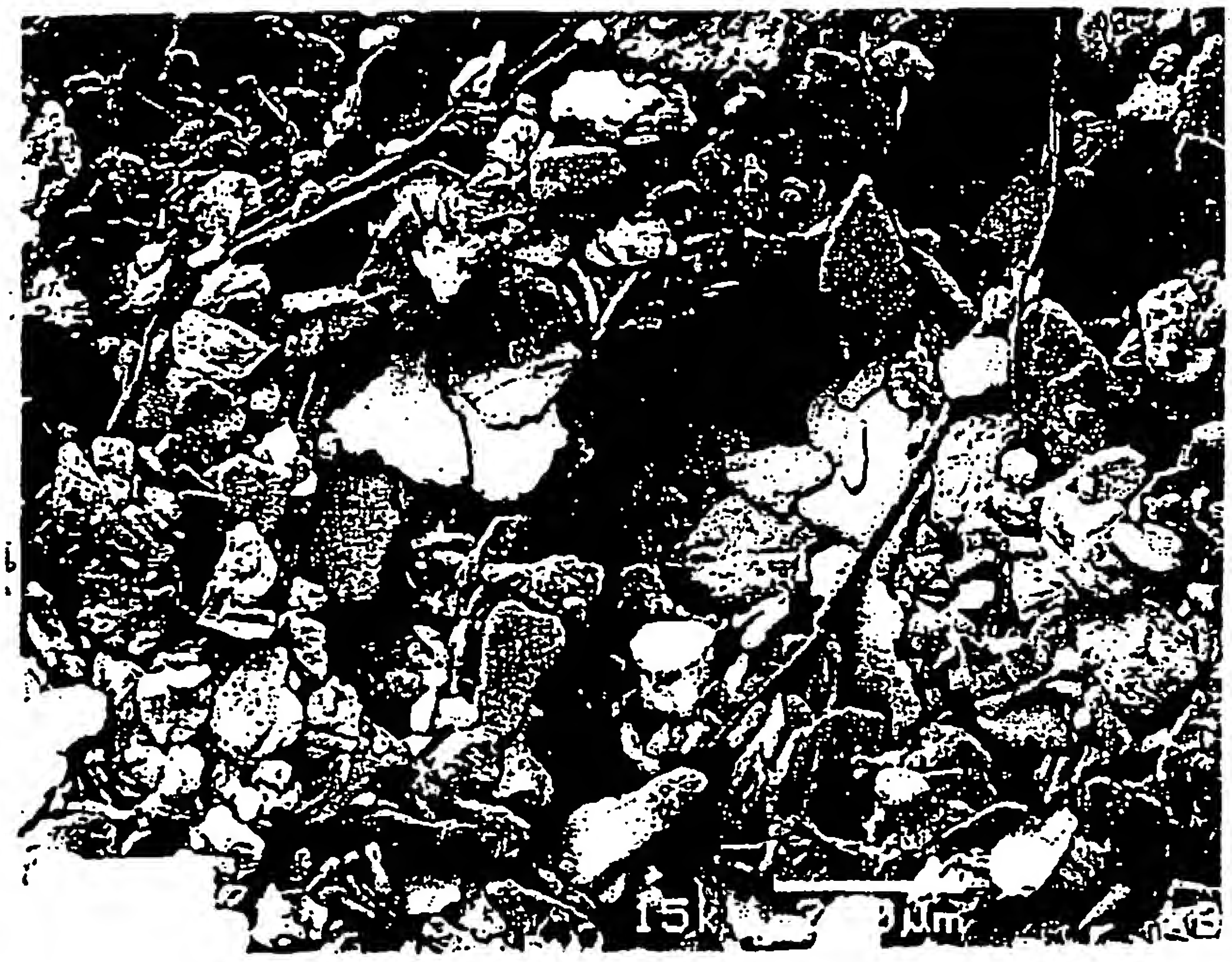


FIG.10a

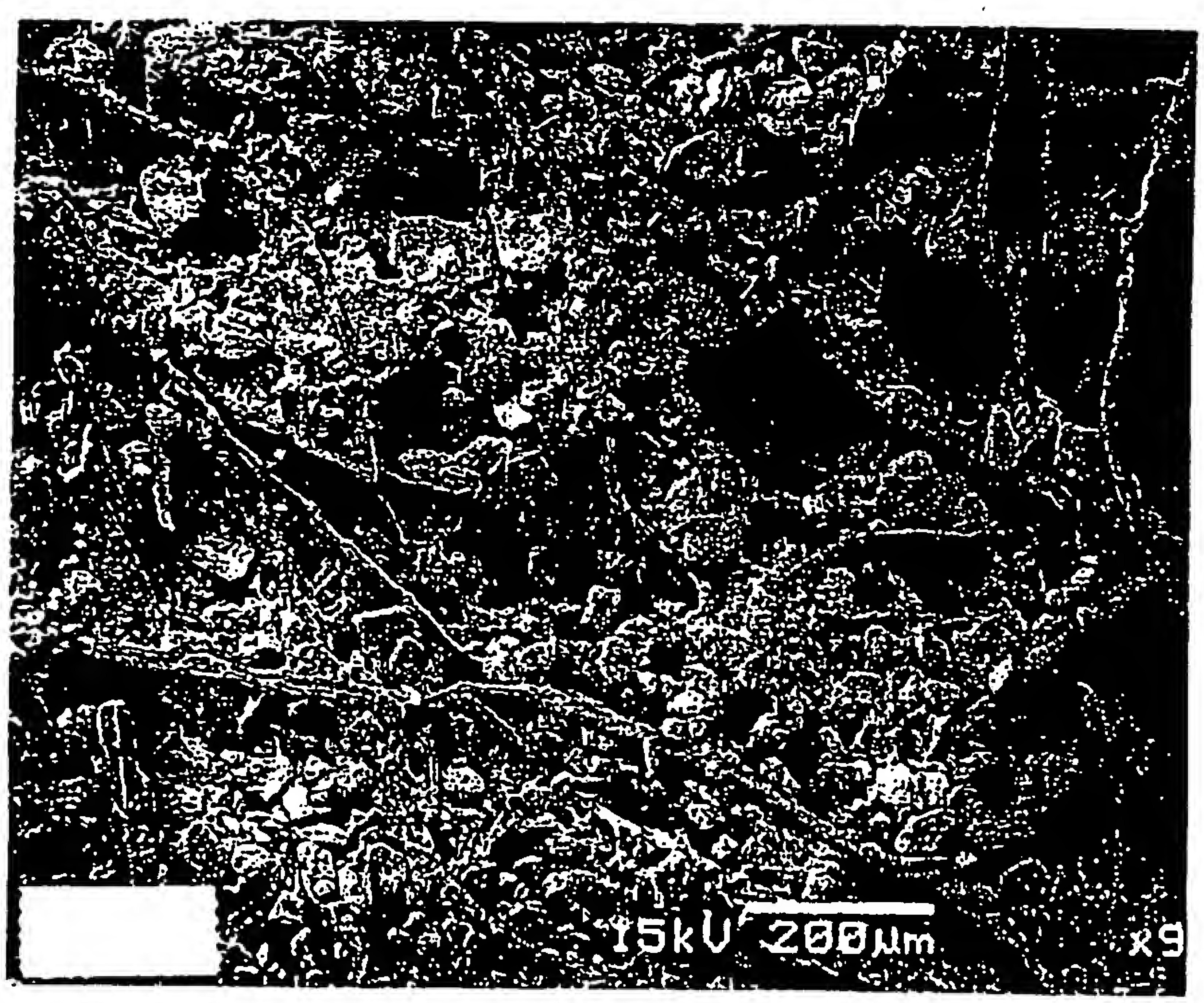


FIG.10b

FIG.10c

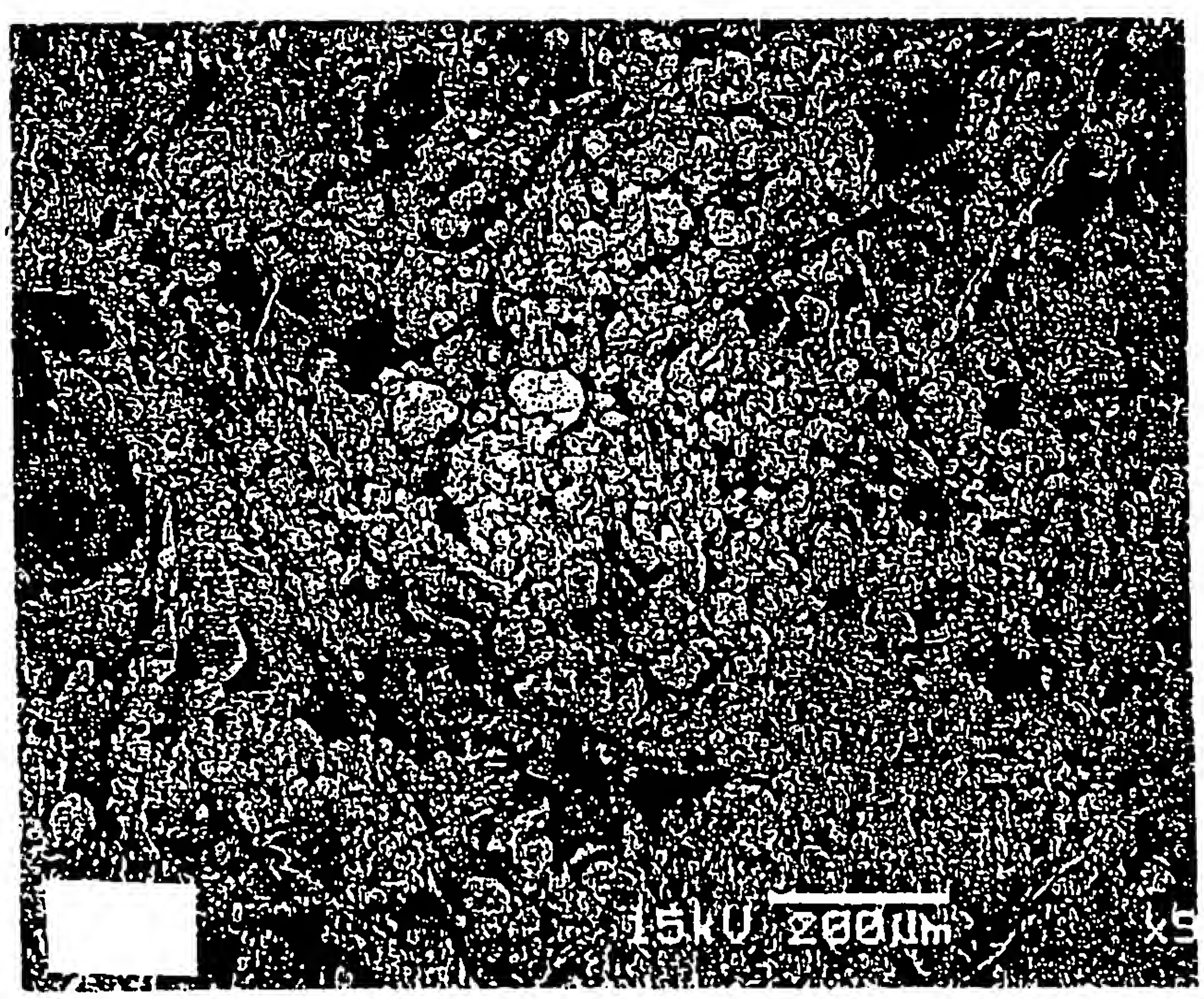


FIG.10d

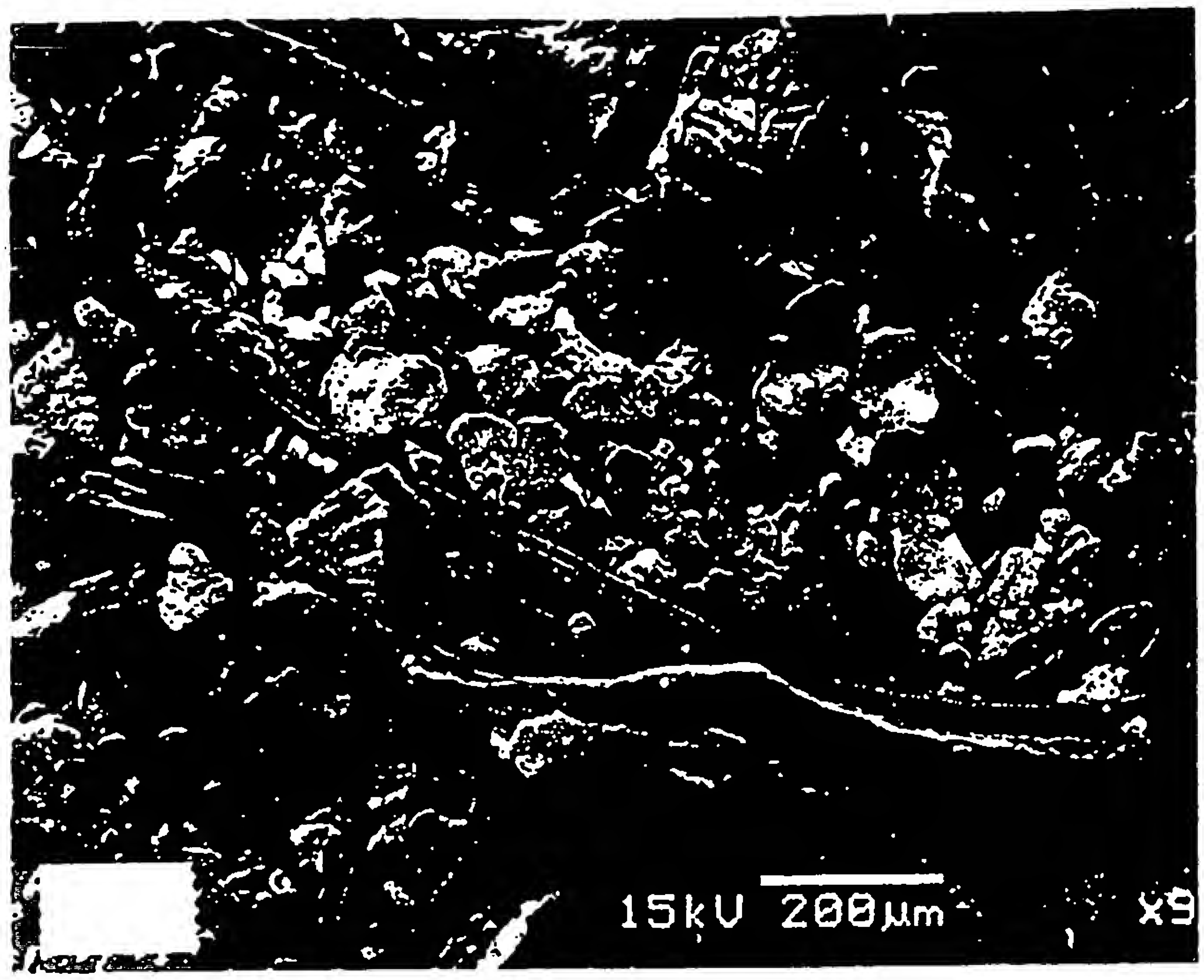


FIG. 11a

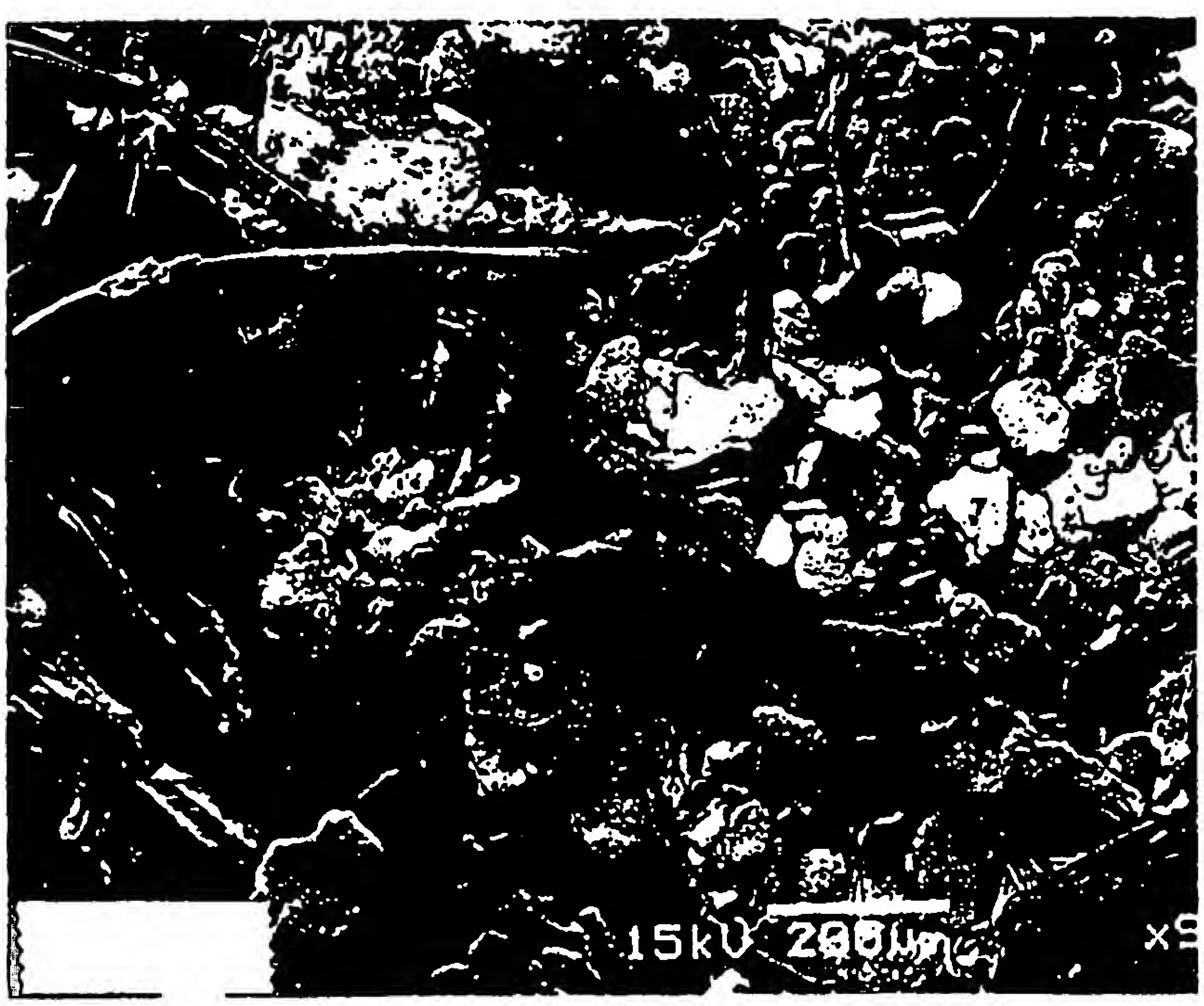


FIG. 11b

FIG.11c

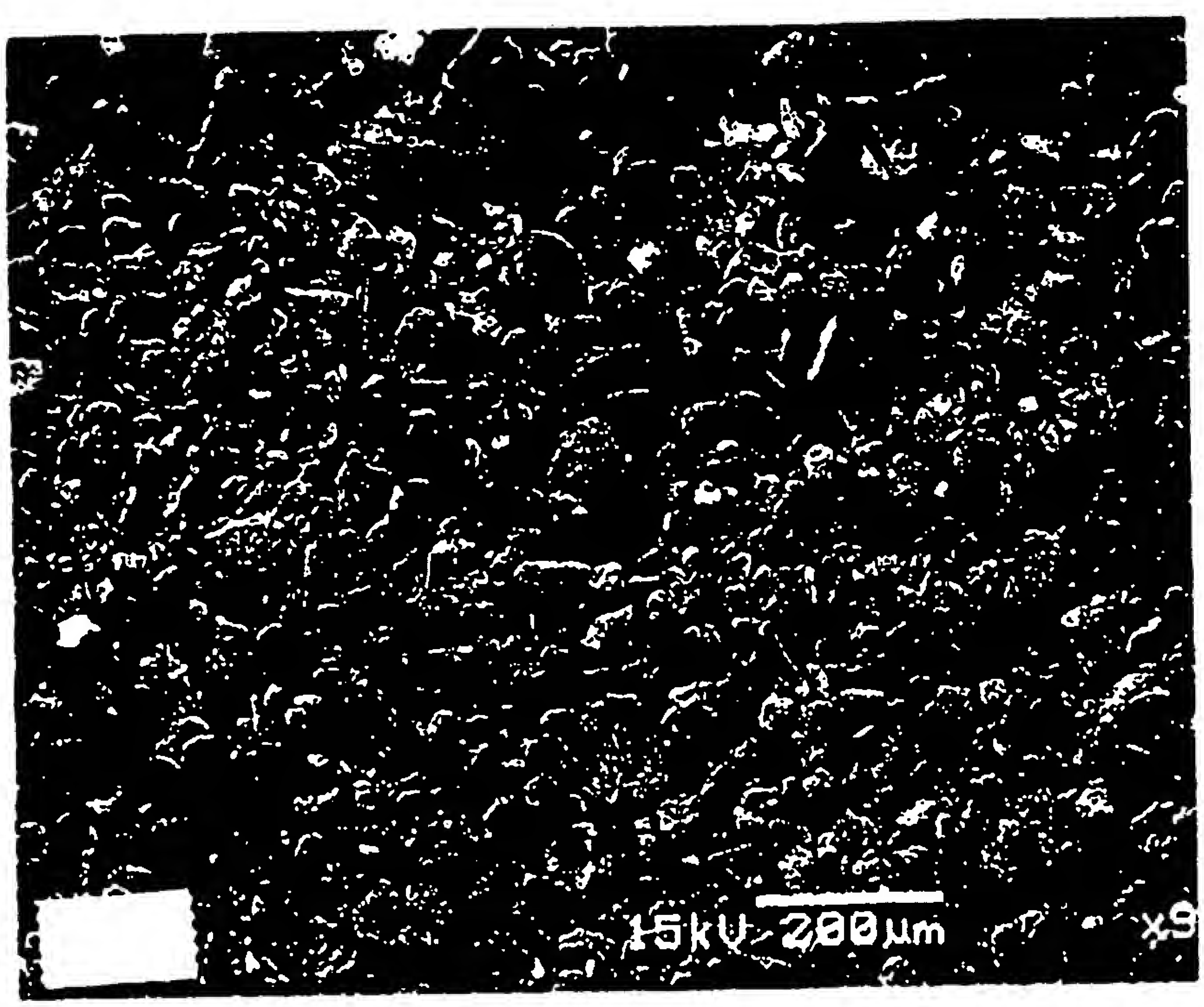
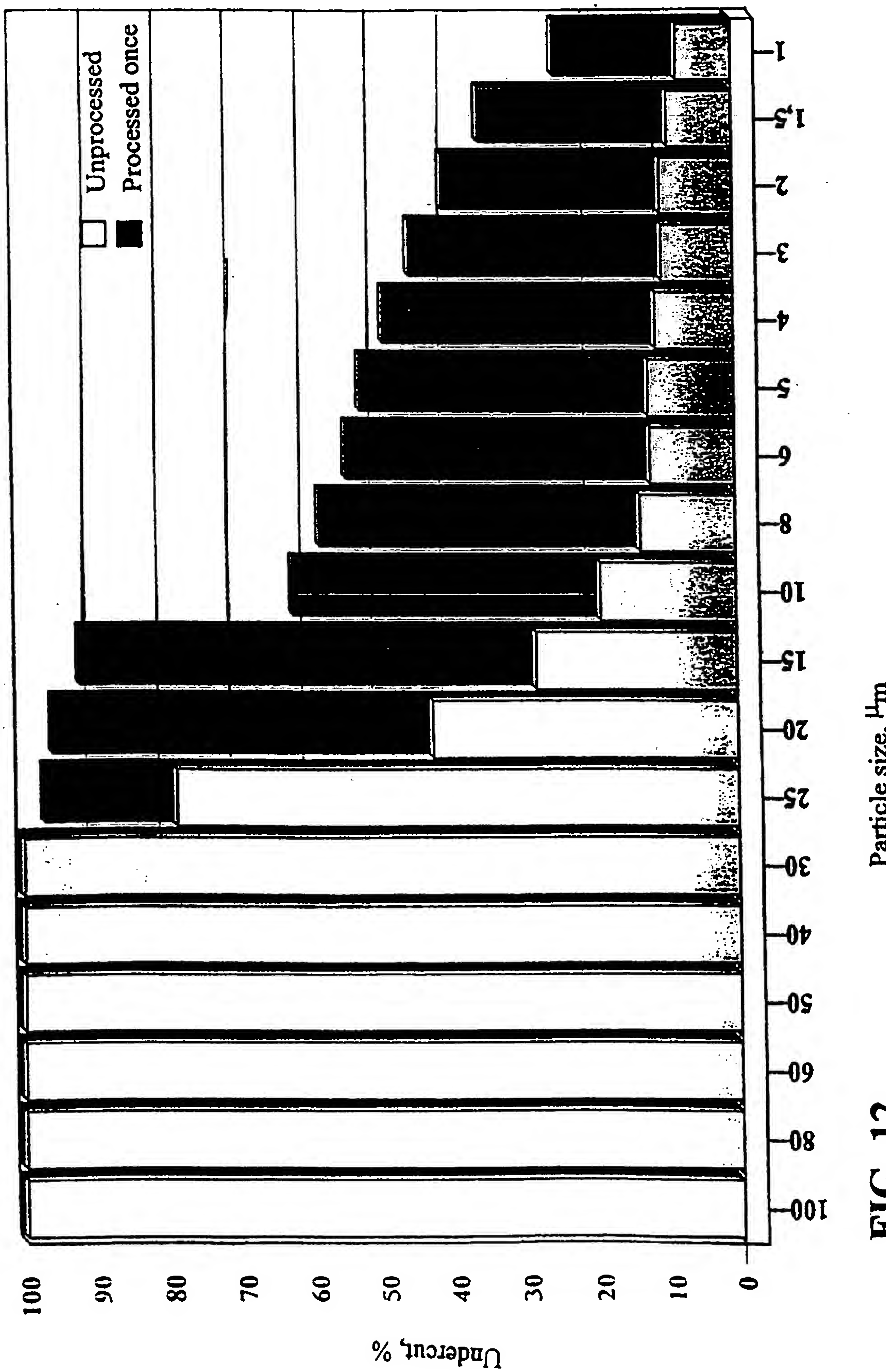


FIG.11d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70
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30
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0
Particle size, μm
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2
3
4
5
6
8
10
15
20
25
30
40
50
60
80
100

FIG. 12